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REVIEW OF FLIGHT TESTS OF NACA C AND D

COWLINGS ON THE XP-42 AIRPLANE

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MEMORANDUM REPORT

for the

Army Air Forces, Materiel Command

REVIEW OF FLIGHT TESTS OF NACA C AND D

COWLINGS ON THE XP-42 AIRPLANE

By J. Ford Johnston

SUMMARY

Results of flight tests of the performance and cooling characteristics of three NACA D cowlings and of a conventional NACA C cowling on the XP-42 airplane are summarized and compared. The D cowling is, in general, characterized by the use of an annular inlet and diffuser section for the engine-cooling air.

The D cowlings tested were a long-nose high-inlet-velocity cowling, a short-nose high-inlet-velocity cowling, and a short-nose low-inlet-velocity cowling.

Increases of the maximum speed were obtained by use of the D cowlings as compared with the conventional C cowling arrangement. The increases corresponded to an over-all drag coefficient reduction of 7 percent with the long-nose cowling, 6 percent with the short-nose low-inlet-velocity cowling, and 4 percent with the short-nose high-inlet-velocity cowling.

Small increases of the cooling pressure recovery in the full-power climb condition were also obtained by the

long-nose high-inlet-velocity and the short-nose low-inlet-velocity cowlings, but the pressure recovery with the short-nose high-inlet-velocity cowling was less than that with the C cowling.

The use of wide-chord propeller cuffs or an axial-flow fan with the D cowlings increased the cooling pressure recoveries in the climb condition at the expense of some of the improvement in speed.

INTRODUCTION

In an extensive investigation directed toward improvement of radial engine cowlings, the NACA has developed the type D cowling, characterized by the use of an annular inlet and diffuser section for the engine cooling air. The development of what was considered the optimum D cowling is described in reference 1. This long-nose cowling was built for the XP-42 airplane, which originally had a Pratt & Whitney 1830-31 engine with an extended propeller shaft placing the propeller about 20 inches ahead of the normal position. Further wind-tunnel investigations, as described in reference 2, were directed toward adapting the D cowling to the standard short-nose engine and again used the XP-42 airplane as a model.

The principal objectives of the wind-tunnel investigations were reduction of external drag and increase of critical Mach number by smoothing the external flow and reducing

the negative pressure peak, and reduction of cooling drag by increasing the cooling air pressure recovery.

The three principal variations of the D cowling which resulted from these investigations were a long-nose high-inlet-velocity cowling, a short-nose high-inlet-velocity cowling, and a short-nose low-inlet-velocity cowling originally designed for use with a spinner-mounted axial-flow fan. These cowlings were then built for flight investigation of their performance and cooling characteristics on the XP-42 airplane. Tests of a conventional NACA C cowling on the same airplane were also carried out for purposes of comparison. Table I lists the various cowlings investigated and the modifications of auxiliary apparatus (propeller cuffs and/or fan) tested on each. The results of these flight tests were reported as soon as possible after the completion of each series and are contained in references 3 to 8. The present paper comprises a summary of these results and a comparison of the drag and cooling characteristics of the cowling arrangements investigated.

The design of the cowlings and engine installations was a project of the Air-Cooled Engine Installation Group stationed at the Laboratory. The members of the group associated with this project included Mr. Howard S. Ditsch of the Curtiss-Wright Corporation, Mr. Peter Torraco of the Republic Aviation Corporation, Mr. William S. Richards of the Wright Aeronautical

Corporation, and Mr. James R. Thompson of Pratt & Whitney Aircraft. The Materiel Command, Army Air Forces sponsored the investigation and supplied the XP-42 airplane. The Curtiss-Wright Corporation, Airplane Division, handled the construction as well as the structural and detail design of the cowlings and supplied personnel to assist in the servicing and maintenance of the airplane and cowlings during the tests. Pratt & Whitney Aircraft prepared the engine and torque meters for the tests and assisted in the operation and servicing of the engine. The propellers, cuffs, and spinners were supplied by the Curtiss-Wright Corporation, propeller division.

The flight tests were conducted at Langley Field from May 1941 to December 1942.

D COWLING DESIGNATIONS

Basic cowling designations have been defined in reference 2, in which the D cowling designations listed were D_l, D_s, and D_{sf}. The subscripts l and s refer to designs suitable for long-nose and short-nose engines, respectively, and f indicates the use of a fan at the cowling entrance. For convenience in differentiating between the two short-nose D cowlings, numerical subscripts will be used in this report to designate the design inlet-velocity ratio. Thus $D_{s.5}$ refers to the short-nose high-inlet-velocity cowling, which was designed for an inlet-velocity ratio of 0.5; and $D_{s.3}$

refers to the short-nose low-inlet-velocity cowling, which was designed for an inlet-velocity ratio of 0.3.

SYMBOLS

q_c airplane impact pressure, inches of water

p pressure above free-stream static pressure, inches of water

Δp cooling-air pressure drop across engine, inches of water

σ free-air density ratio

t_a free-air temperature, $^{\circ}F$

t_h average cylinder-head temperature, $^{\circ}F$

bhp engine brake horsepower

APPARATUS AND METHOD

XP-42 Airplane

The XP-42 airplane as tested was a P-36 airplane with the exception of the engine installation and the fuselage side fairings behind the cowling. The engine was a 14-cylinder twin-row Pratt & Whitney R-1830-31, incorporating an extended nose section which placed the propeller about 20 inches ahead of the normal position. This extension was replaced by a standard nose for the tests with the short-nose D and C cowlings. The power rating of the engine was as follows:

	Brake horsepower	rpm	Altitude, ft
Take-off	1050	2550	0
Normal rating	1000	2300	8,500
Normal rating	1000	2450	11,500
Military rating	1000	2700	14,500

The engine had a single-stage blower with an impeller drive ratio of 8.47:1 and a propeller drive ratio of 9:16. A special set of cylinder baffles, designed to minimize the leakage of air between adjoining baffles and to fit more closely to the fins, was provided by the engine manufacturer.

Individual-cylinder exhaust jet stacks, designed according to reference 9, were used in place of the standard collector ring. The cross section at the exhaust port was about 4.05 square inches, and the nozzle area at the end averaged about 2.98 square inches.

The airplane, as prepared for the tests, weighed 6000 pounds with pilot and full tanks. It retained the standard aerial but had no provisions for guns.

Cowlings

Dimensioned drawings of each cowling are shown in figures 1 to 4. The ordinates of the long-nose cowling are given in reference 1, those of the short-nose (D_s) cowlings in reference 2, and those of the C cowling in reference 10. The long-nose cowling (fig. 1) was designed to induct the engine cooling, carburetor and oil-

cooler air through the single annular inlet, at about half the the airplane velocity in the high-speed condition; that is, the design inlet velocity ratio was 0.5. The carburetor and oil-cooler air supplies were divided off by a "splitter ring" in the low-velocity region at the end of the diffuser section. The sections of the wide-chord propeller cuffs were symmetrical at the root, as shown in figure 1, and tapered to conform with the propeller section at about the 22-inch radius. Views of the cowling as installed on the airplane are shown in figure 5.

The short-nose high-inlet-velocity $\left(D_{s.5}\right)$ cowling, figures 2 and 6, had separate external scoops at the cowling lip for the induction and oil-cooling air. The annular inlet for the engine cooling air, designed for an inlet velocity ratio of 0.5 in the high-speed condition, was located at as large a radius as possible to aid the ground cooling. In order to reduce the thickness of the boundary layer in relation to the resultant narrow inlet gap, the spinner was reflexed slightly near the trailing edge, as may be seen in figure 6. The propeller cuff sections were symmetrical at the root, as shown in figure 2, and tapered to conform with the propeller section at about the 22-inch radius.

The short-nose low-inlet-velocity $\left(D_{s.3}\right)$ cowling, figures 3 and 7, had the same external cowl as cowling $D_{s.5}$.

The design inlet-velocity ratio was reduced to 0.3 by the use of a smaller, nonreflexed spinner, and a new afterbody and cowling inner liner which increased the inlet area. Both sets of cuffs differed from the previous sets in that the camber line of the root section was reflexed from about the midchord point. Details of the spinner-mounted fan and of the cuffs are contained in references 5 and 6, respectively.

The NACA C cowling, shown in figures 4 and 8, was made from cowling D_s. The narrow-chord cuffs and 24-inch diameter spinner were of standard commercial manufacture for the propeller used.

The small cowl flaps originally provided for the airplane, shown in figures 1 to 5, proved inadequate for the climb tests, and three additional cowl flaps were installed on each side. The modified cowl flaps are shown in figures 5(d) and 6(c). The position of the extra cowl flaps could be changed only on the ground. They were fixed closed for the high-speed tests and full open (approximately 35°) for the climb and ground-cooling tests. There was some flexibility and lost motion in their supporting mechanism but the cowl flap openings were not recorded in flight.

Test Equipment

The test equipment used during the investigation is described in references 3 and 4. The quantities measured by the recording instruments included an extensive survey of the

engine cooling, induction and oil-cooler air pressures; all cylinder-head and barrel-flange temperatures, along with certain engine accessory and air temperatures; the engine power and manifold pressure; and the airspeed and altitude.

High-Speed Tests

The high speed was determined in each case by making a series of about 10 level runs at full throttle, 2700 rpm, at and above the engine critical altitude (from 14,500 to 19,000 feet). The cowl flaps were closed, carburetor heat off, and mixture control in automatic rich. All quantities were measured after stabilization in the run.

High-speed tests 1, 3, and 4 (table I) were made with the original small cowl flaps; and the later tests, with the modified cowl flaps. Comparison of the results of test 4 with those of tests 6 and 7 showed that the modified cowl flaps caused a speed loss of 2 miles per hour. This loss is attributed to air leakage around the modified flaps, and would not be present in a well-designed cowl flap installation. In order to keep the results of all the cowling tests on a comparable basis, therefore, the speeds observed in tests using the modified cowl flaps have been raised by 2 miles per hour for quotation in this report.

Climb Tests

Two sustained climbs to about 20,000 feet were generally made with each cowling arrangement. One was at 140 miles per hour indicated airspeed, full rich, 2550 rpm, with the manifold pressure kept at about 43 inches Hg to 7000 feet, then 42 inches until the full-throttle position was reached. The other was at 155 miles per hour indicated airspeed, automatic rich, 2550 rpm, with the manifold pressure at about 40 inches Hg to full throttle. The automatic-rich setting provides a mixture compensation for altitude which is bypassed in the full-rich setting.

Ground Cooling

Ground-cooling tests were made by running the engine at 1380 rpm for about 10 minutes, then idling 5 minutes and shutting off after clearing the plugs. Engine cylinder, accessory and air temperatures were recorded during the running periods and for 10 minutes after the engine was stopped. The propeller was in low pitch, cowl flaps were full open, and the airplane was sidewise to the wind. The ground-cooling test of the long-nose cowling was made with only the original small cowl flaps; the modified cowl flaps were used in the ground tests of the other cowlings.

RESULTS AND DISCUSSION

The maximum speed at rated military power and altitude and the engine cooling-air pressure recovery for each cowling

arrangement are listed in table I. These values, the one relating to the cowling drag and the other to the relative engine-cooling capacity, are considered the most important features of cowling performance. More complete results are contained in references 3 to 8.

Maximum Speed

At the Mach number (about 0.45) at which the high-speed runs were made, the maximum difference in speed between the cowlings was slightly over 2 percent of the maximum speed, and corresponded to a 7-percent change in the airplane drag coefficient. From external pressure-distribution tests in the wind tunnels, the expected critical Mach number for cowling D_1 was about 0.74; for cowling $D_{s.5}$, about 0.70; and for cowling C, about 0.63. The external pressure distribution on cowling $D_{s.3}$ was not measured. If the cowlings had been tested at higher Mach numbers, it is expected that the speed differences would amount to a larger proportion of the maximum speed.

The grouping according to speed was roughly the same as the grouping according to expected critical Mach number, with the possible exception that cowling $D_{s.3}$ showed lower drag than cowling $D_{s.5}$. In this case, it appears that the improvement of external flow usually associated with the higher inlet velocity was not realized.

<u>Effect of ram on speed.</u> - The speed comparison of table I, made on the basis of operating at the rated military power and altitude, assumed zero carburetor ram; that is, it assumed that the air density at the carburetor was equal to the free-air density. Where ram is available, the accompanying density rise at the carburetor increases the altitude to which the rated power can be maintained, and therefore increases the maximum speed obtainable. For the short-nose cowlings with the external scoop, the ram averaged $1.0q_c$; but the internal ducting arrangement of the long-nose cowling reduced the ram for that installation to $0.75q_c$. With the ram and the accompanying temperature rise in the carburetor duct due to the adiabatic compression and to heat absorption through the duct walls, the carburetor air densities were about 5 percent above free-air density for the long-nose cowling, and 8 percent for the short-nose cowlings. The corresponding increments of speed due to this increase of critical altitude would be about 5 miles per hour for cowling D_l and 8 miles per hour (above the values quoted in table I) for the other cowlings. On this basis, cowling $D_{s.3}$ would show a slightly higher speed than cowling D , even though its basic drag was somewhat greater. The internal ducting of cowling D must be improved before the external drag reduction can be fully exploited.

Effect of fan and cuffs on speed. - Table I shows that the fan tested with cowling $D_{s.3}$ reduced the top speed by approximately 4 miles per hour and increased the cooling pressure recovery at high speed by about $0.08q_c$. The pressure rise calculated from tests of similar fans (reference 11) was also $0.08q_c$. The calculated fan power absorption was about 15 horsepower, or the equivalent of a 2-mile-per-hour reduction in top speed. The difference between the calculated and measured speed losses is within the combined accuracy of measurement of the two speeds involved.

The wide-chord propeller cuffs tested with the D_s cowlings cost from 1 to 4 miles per hour in top speed and had varying effects upon the pressure recovery in the high-speed condition. In each case, however, they increased the pressure recovery in the full-power climb condition by about $0.1q_c$. It appears from these data that wide-chord propeller cuffs may be used for improving climb cooling which will have little or no effect upon the maximum speed, but that the effect on the speed may be critically dependent on the cuff setting or shape.

In contrast to the wide-chord cuffs, the narrow-chord cuffs of cowling C had negligible effect upon the engine-cooling pressures in flight, but resulted in a speed increase of about 1 mile per hour.

Engine Cooling-Air Pressures

The average cooling-air pressures on the front of the engine for each cowling arrangement are listed in table I.

Basic pressure recoveries. - Of the four cowlings, the $D_{s.5}$, $D_{s.3}$, and C were tested in the basic condition, that is, without fan or cuffs. The difference in pressure recovery between these basic cowlings was negligible in the high-speed condition, as is shown by the pressure recoveries of 74, 76, and 74 percent of free-stream impact pressure. It is probable that cowling D_l, if tested without cuffs, would have shown very nearly the same pressure recovery as the other cowlings.

In the 140-mile-per-hour climb condition, where the cooling is more critical, some difference appeared between the basic cowlings. The pressure recovery with cowling $D_{s.5}$ dropped from $0.74q_c$ in the high-speed condition to $0.62q_c$ in the climb condition; with cowling C, from $0.74q_c$ to $0.67q_c$; and with cowling $D_{s.3}$, from $0.76q_c$ to $0.74q_c$. Some decreased recovery is usually expected to accompany the increase in angle of attack. With cowling $D_{s.5}$, this loss was augmented by an increase of the inlet-velocity ratio to about 0.7, which was well beyond the optimum for the short length of diffuser available. With cowling $D_{s.3}$, on the other hand, the increase of inlet-velocity ratio to about 0.45 apparently improved the flow to offset the expected loss due to increased angle of attack.

Direct comparison of the pressure recovery in climb of cowling D_l with that of the other cowlings is somewhat difficult because it was not tested without cuffs. When it is noted, however, that the other wide-chord cuffs gave pressure increments in the 140-mile-per-hour full-power climb condition that ranged only from $0.08q_c$ to $0.12q_c$, then it appears probable that the pressure recovery in climb with cowling D_l, without cuffs, would correspondingly have been from $0.08q_c$ to $0.12q_c$ lower than that observed with the cuffs. The probable pressure recovery in climb of cowling D_l without cuffs is then from $0.74q_c$ to $0.78q_c$. These figures compare favorably with the pressure recoveries observed with the other cowlings in the basic condition.

Although the comparison is favorable, it does not represent the full potentialities of the diffuser used with the long-nose cowling. The pressure recovery on the front of the engine was $0.12q_c$ less than the total pressure of the air in the low-velocity region at the end of the diffuser. This low-velocity air was forced to undergo a considerable velocity increment in passing through the "splitter ring," and failure to recover the kinetic energy so attained caused the quoted loss of $0.12q_c$. These considerations lead to the conclusion that a basic pressure recovery without cuffs of as high as $0.85q_c$ would probably be available in a similar long-nose cowling design which took full advantage of the diffuser.

Pressure recoveries with fan or cuffs. - Whereas the wide-chord cuffs raised the cooling-pressure recoveries in climb by about $0.1q_c$, as has been noted, the fan with cowling $D_{s.3}$ raised the pressure recovery by about $0.25q_c$, or $2\frac{1}{2}$ inches of water. According to reference 11, some further increases may be obtained by using a fan of greater solidity or by using contravanes. If large increases of cooling pressure are required, however, the fan must be operated at higher speeds, that is, geared above propeller speed.

Pressure distribution around engine. - The observed distributions of cooling pressures around the engine are plotted in figures 9 and 10 for several cowling arrangements. The distributions in the high-speed condition, figure 9, were fairly uniform for all the cowlings, as would be expected. In the climb condition, the distributions were less uniform and there was a general tendency toward higher pressures at the bottom and lower left of the cowling. No significant differences between the cowlings are discernible from these figures, although perhaps a more complete survey would have revealed them.

Radial distribution. - The radial pressure distributions for several cowling arrangements are plotted in figure 11 for the high-speed condition and in figure 12 for the climb condition. Each point through which a curve is drawn was averaged from

measurements on four or five different cylinders, but the points shown at 1.2 inches from the cylinder base in figure 11 were measured only on cylinder 4 in the case of the front cylinders and only on cylinder 3 in the case of the rear cylinders. These points near the bottom of the cylinder are believed to be indicative of the trend of distribution but do not as closely represent the average distribution as do the other points. Figures 11 and 12 show the effect of the annular jet from the diffuser section upon the cooling pressures up and down the cylinder. The jet effect was confined principally to the front cylinders and was more pronounced in the climb condition. The high-inlet-velocity cowlings showed more effect than the low-inlet-velocity cowling, but with cowling D_l the jet effect resulted from velocity acquired by the air in passing through the "splitter ring" rather than from the velocity remaining at the exit of the long diffuser passage. The jet localized the high-pressure region near the juncture of the cylinder head and barrel at the expense of the pressures at the ends of the cylinder. No apparent adverse effects upon the cylinder-head cooling resulted from this radial pressure distribution, as the jet was so placed as to cover the hottest parts of the cylinder and to supply high-pressure air at the base of the vertical head fins.

The deficiency of pressure near the base of the cylinders was found to be characteristic of the C cowling as well as of the D cowlings. Correspondingly, the barrel temperatures, measured at the rear center line of the flange at the base of the cylinder, were marginal or exceeded the Army limit in both the climb and high-speed conditions with all the cowlings tested.

Engine Temperatures

From the beginning of this investigation it has been emphasized that appraisal of a cowling on the basis of engine temperatures alone can be regarded as reliable only to the extent that the effects of all other factors influencing engine temperatures can be evaluated. Principal among these factors were the cylinder fin-and-baffle combination and the engine fuel-air ratio.

Effect of mixture distribution. - It was found that in no case was there any apparent correlation between cooling-air pressure distribution and cylinder-temperature distribution around the engine, and variations in mixture distribution between cylinders were suspected of obscuring the effect of the cooling-air distribution. Analysis of exhaust samples taken from cylinders 1 and 11 in high-speed level flight indicated that the fuel-air ratio in cylinder 1 was about 0.11, while that in cylinder 11 was approximately 0.095. Correspondingly, cylinder 11 was about 65° F hotter than cylinder 1.

Further evidence of the effect of mixture distribution was a complete change of the temperature-distribution pattern observed in the full-rich climbs as the mixture strength increased with altitude, although the cooling-air pressure distribution was unchanged.

Effect of the special baffles. - Throughout the investigation the cylinder-head temperatures remained well below their limit of 500° F, but the cylinder-base temperatures were either close to or above their limit of 335° F when corrected to Army conditions. A deficiency of pressure at the base of the cylinders has already been noted as a contributing factor, but it was understood that a similar type of engine, with standard baffling and in a C cowling, had performed satisfactorily in so far as the barrel temperatures were concerned. Therefore, nine of the 14 small sealing strips which prevented air leakage between the cylinder barrels, below the lowest barrel fins, were removed for a series of high-speed runs (test 7 only). With this more nearly standard baffle arrangement, which allowed a flow of relatively cool air around the base thermocouples, the maximum barrel-temperature indications were reduced by about 18° F, although the head temperatures were unchanged. A reduction of this magnitude would be sufficient to reduce barrel-temperature indications to or below the Army limit

for all the cowlings tested. If any substantial improvement of the actual barrel cooling were desired, however, it would be necessary to improve either the cooling-pressure distribution or the barrel finning.

Relation of temperatures to cooling pressures. - The relation between the average cylinder-head temperatures and the cooling-air pressure drops in the high-speed runs made with cowlings $D_{s.5}$, $D_{s.3}$, and C is shown in figure 13. For this presentation, the observed temperature differences were corrected to 900 brake horsepower on the assumption that $(t_h - t_a) \propto (bhp)^{0.7}$. The remaining experimental scatter is believed to be largely a result of flight-to-flight variation of the fuel-air ratio and hence of the effective gas temperature. No correction could be made for changes in the fuel-air ratio as measurements of the fuel-air ratio that could be considered reliable were obtained only once, near the end of the tests. It is known, however, that the fuel-air ratio decreased with the engine manifold pressure and therefore with increasing altitude above the critical altitude. Hence, if it had been possible to correct each point for fuel-air ratio, the principal result, apart from a reduction in the experimental scatter, would have been a reduction in the slope of the correlation curve since the leaner mixtures and higher gas temperatures invariably occurred with the lower values of $\sigma\Delta P$, that is, at the higher altitudes.

On the assumption that the fuel-air ratio and gas temperatures varied over the same range during the tests of each cowling, the fact that the points for all cowlings group about a common line indicates that the cooling for a given pressure drop was essentially the same regardless of the type of cowling. It follows, then, that the cowling which has the highest pressure recovery on the front of the engine has the best potential cooling capabilities.

Ground Cooling

Cylinder-head and barrel temperatures were found to be below their limits during all the ground-cooling runs. The critical items noted were generally the oil-in temperatures while the engine was running and the spark-plug-elbow temperatures after the engine was stopped. During preliminary tests the magneto temperatures were also critical until the accessory compartment venting was improved. The use of propeller cuffs generally brought all temperatures below their Army limits.

Cooling with cuffs. - Time histories of the hottest cylinder-head and spark-plug-elbow temperatures observed during the ground-cooling runs of the four cowlings, with cuffs, are shown in figure 14. Similar plots for cowlings $D_{s.5}$, $D_{s.3}$, and C, without cuffs, are shown in figure 15. To avoid confusion of curves and because the oil-cooling

systems for the short-nose cowlings were identical, the oil-in temperatures are not included. The ground run with cowling D_l was made with only the original small cowl flaps, whereas the other ground runs were made with the modified cowl flaps. From figure 14, cowling D_l appears to have cooled as well as the other D cowlings. The oil-in temperature, however, just equalled its Army limit, whereas with the other cowlings with cuffs, it remained from 5° to 10° F below the limit. The C cowling with spinner and narrow-chord cuffs showed higher cylinder and elbow temperatures than did the D cowlings with wide-chord cuffs, although it was the coolest of the C cowling arrangements.

Cooling without cuffs. - In the runs without cuffs, figure 15, all temperatures were appreciably higher. With cowling $D_{s.5}$, the engine was throttled back to idling after only 5 minutes at 1380 rpm because of excessive indicated oil-in temperatures. The tests with cowlings $D_{s.3}$ and C, without cuffs, were continued in spite of oil temperatures about 20° F above the Army limit. Because of the similarity of the oil-cooling systems, approximately the same oil temperatures might have been expected for cowling $D_{s.5}$ if the run had not been shortened. The hottest spark-plug elbow with cowling $D_{s.5}$ would also have been expected to reach

a maximum comparable with that of cowling $D_{s.3}$, or about 10° F above the Army limit (of 148° F above free-air temperature). With cowling C, the hottest spark-plug elbow reached a maximum about 60° F above the Army limit. In each case, the maximum spark-plug-elbow temperatures were obtained after the engine was stopped.

The results of these ground runs indicate that ground cooling is no more difficult with the D cowlings than with the conventional C cowling.

CONCLUSIONS

The maximum speed of the XP-42 airplane was increased by a change from a C cowling to a D cowling by an amount corresponding to an airplane drag coefficient reduction of 7 percent with the long-nose high-inlet-velocity cowling, 6 percent with the short-nose low-inlet-velocity cowling, and 4 percent with the short-nose high-inlet-velocity cowling.

The engine cooling-air pressure recovery was also increased by the change so long as the inlet velocity was not too high for the diffuser used. The pressure recovery in the full-power climb condition was increased by about 7 percent of free-stream impact pressure ($0.07q_c$) by the short-nose low-inlet-velocity cowling, but it was decreased by about 5 percent q_c by the short-nose high-inlet-velocity cowling. Although direct comparative tests were not made,

it was deduced that the long-nose high-inlet-velocity cowling, modified internally, might be capable of increasing the pressure recovery in climb by about 18 percent q_c as compared with the C cowling.

The use of wide-chord propeller cuffs with the D cowlings increased the pressure recovery in full-power climb by about 1 inch of water (10 percent q_c) and improved the ground cooling, but decreased the top speed by from 1 to 4 miles per hour.

The use of a fan with the low-inlet-velocity cowling raised the pressure recovery in climb by about $2\frac{1}{2}$ inches of water (25 percent q_c) but decreased the top speed by 4 miles per hour.

The ground cooling with the D cowlings, without cuffs, compares favorably with that with the C cowling.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., April 20, 1943.

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Table I - Cowlings tested on XP-42 Airplane

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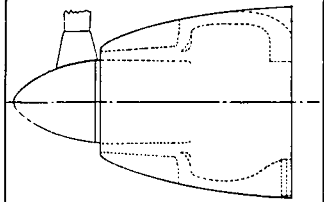
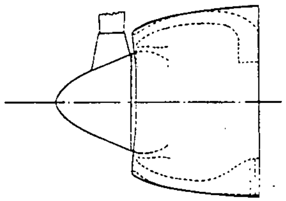
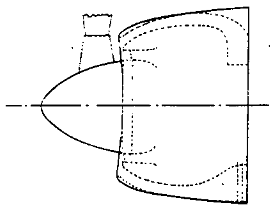
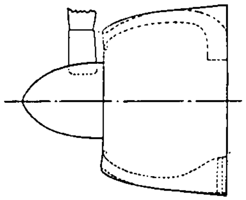
Configuration	Cowling designation	Test number: High speed	Test number: Climb	Accessories	Max. speed at 1,000 hp, 14,500 ft, mph	Cooling air pressure recovery, P/q_c: at high speed	Cooling air pressure recovery, P/q_c: in climb at 140 mph IAS	Cooling air pressure recovery, P/q_c: in climb at 155 mph IAS
	D_l	1	2	Cuffs A	344	.83	.86	.83
	$D_{s.5}$	3	16	Cuffs B	339	.80	.70	.70
		16 B	16A	None	340	.74	.62	.62
	$D_{s.3}$	4, 6, 7*	5	Fan, cuffs 1	337	.87	1.02	.95
		8	9	Fan only	339	.84	.98	.95
		11	10	None	343	.76	.74	.75
		12	13	Cuffs 1 only	339	.80	.86	.81
		15	14	Cuffs 2 only	342	.77	.84	.82
	C	18	17	Spinner and cuffs	339	.69	.58	.58
		19	20	Cuffs only	337	.74	.68	.69
		22	21	None	336	.74	.67	.68

*Nine baffle seals removed for this test only.

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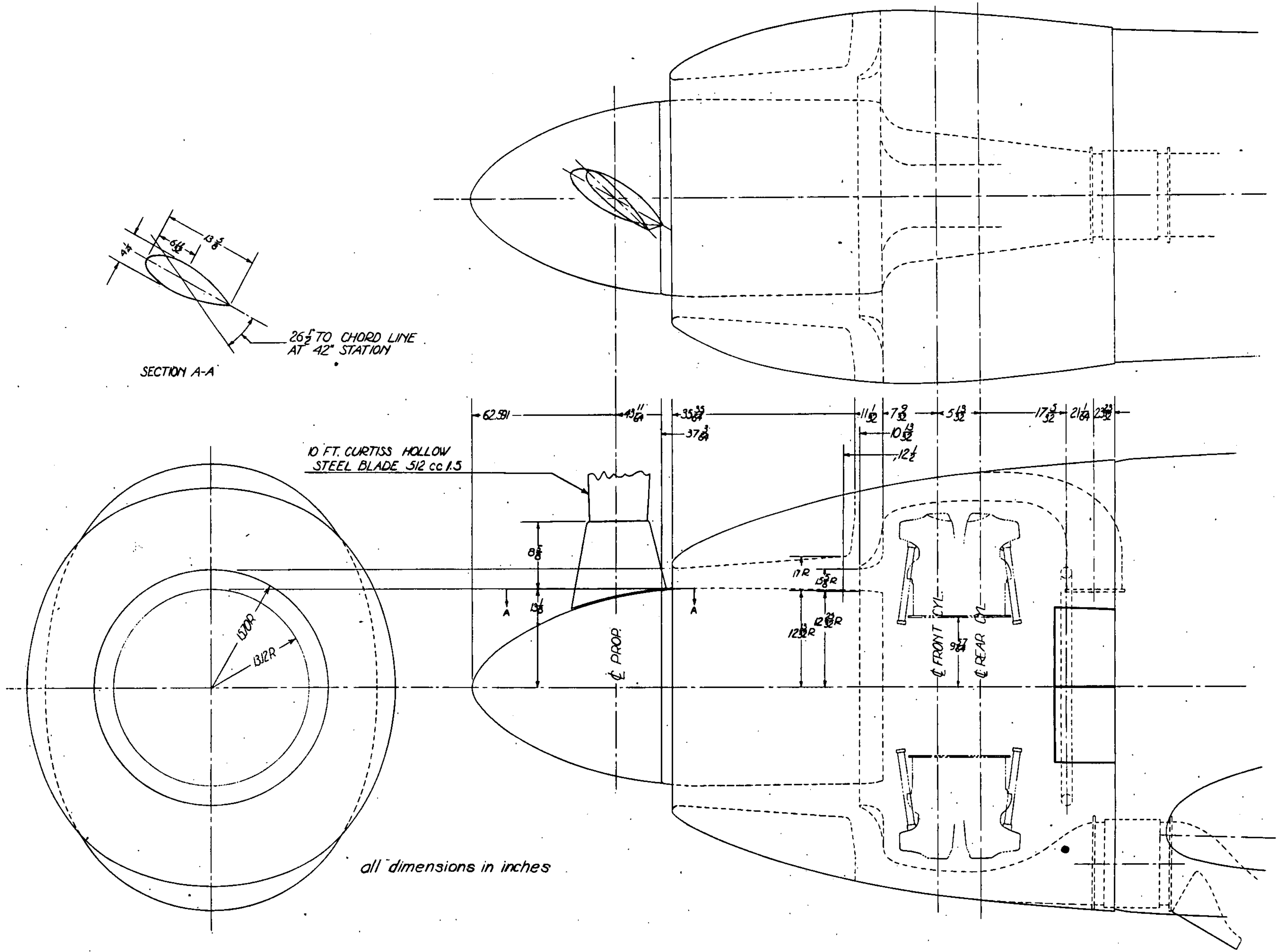

Figure 1.- XP-42 long-nose high-inlet-velocity cowling.

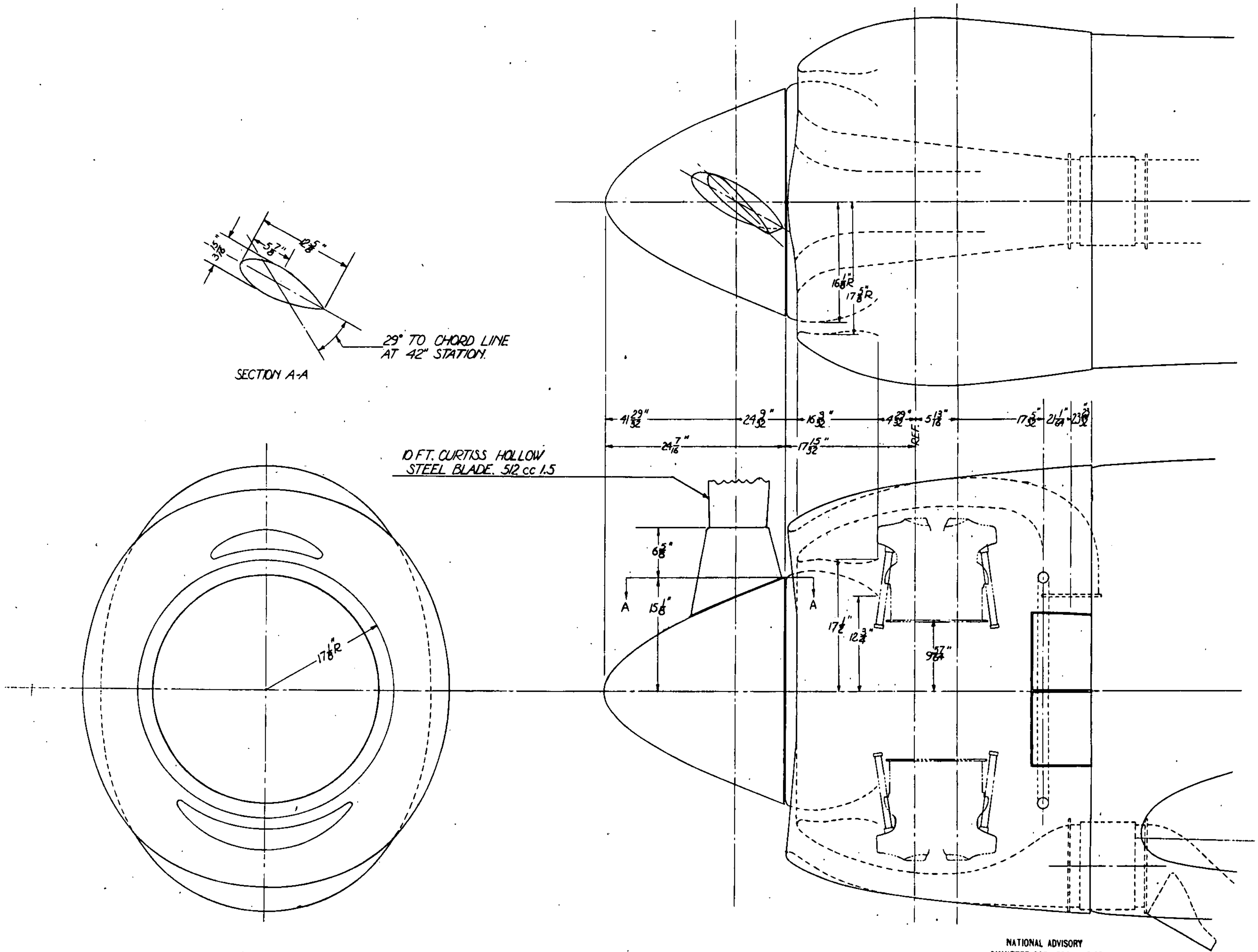

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Figure 2.- XP-42 short-nose high-inlet-velocity cowling.

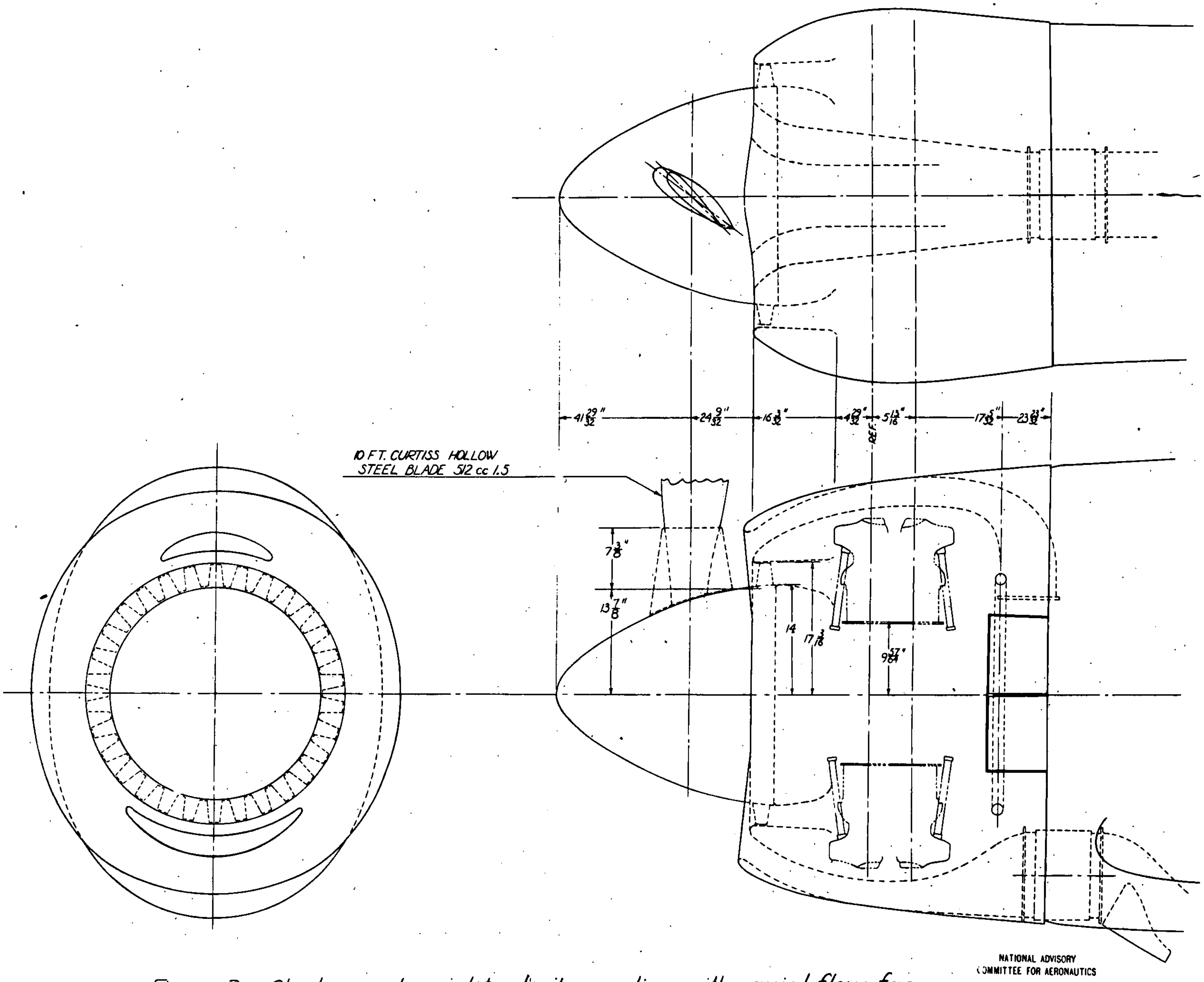


Figure 3. - Short-nose low-inlet-velocity cowling with axial-flow fan.

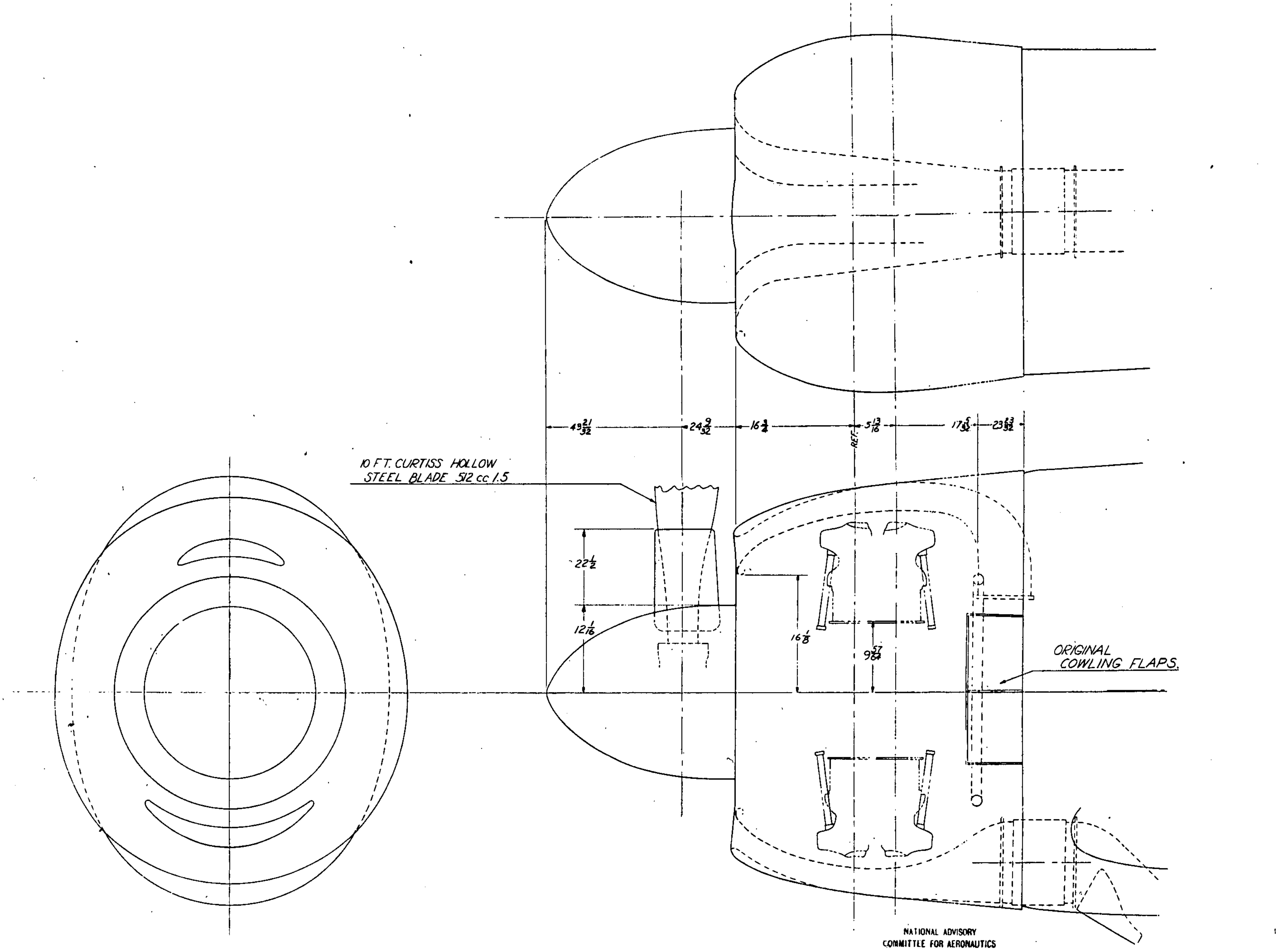
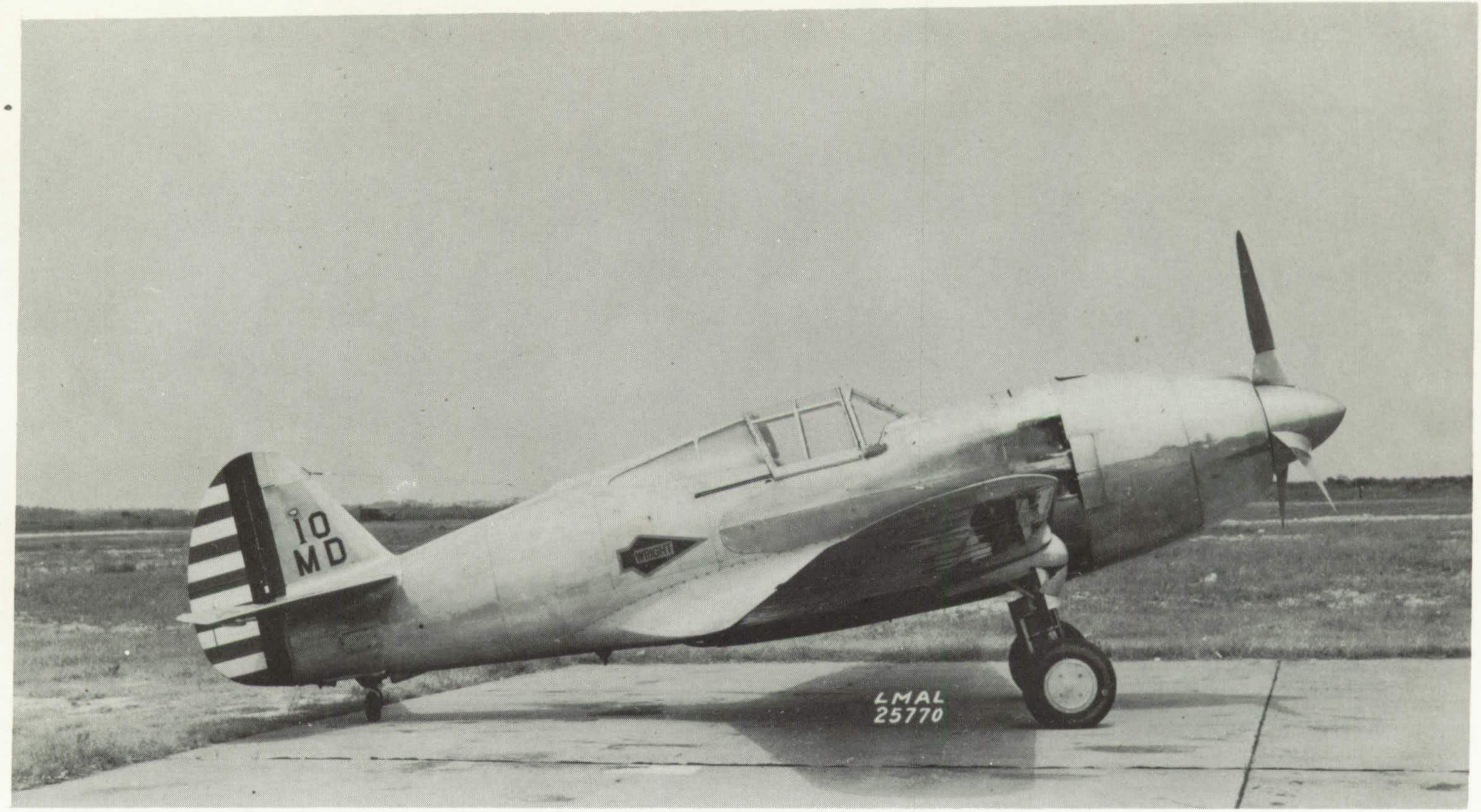
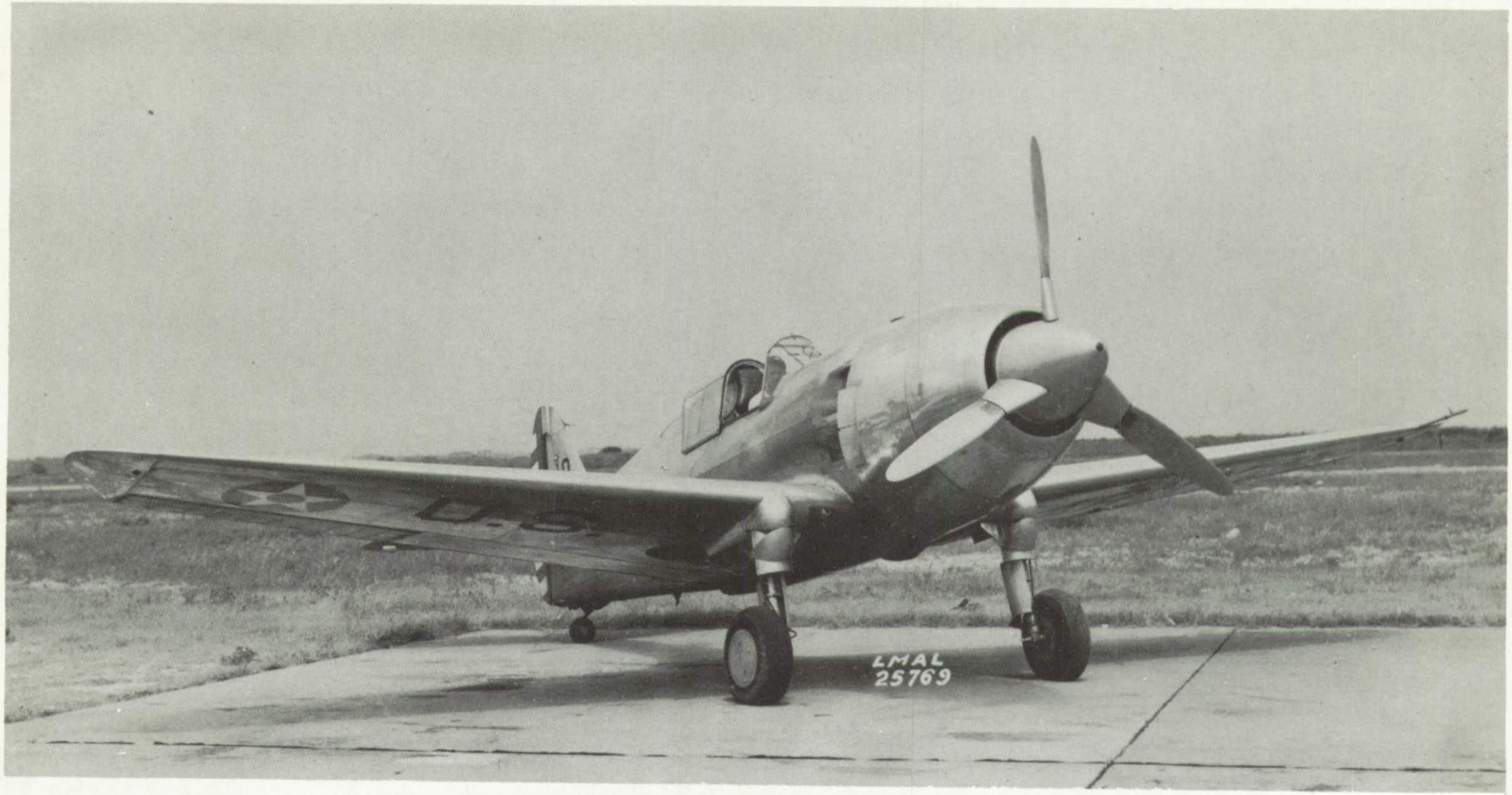


Figure 4.- XP-42 C cowling.



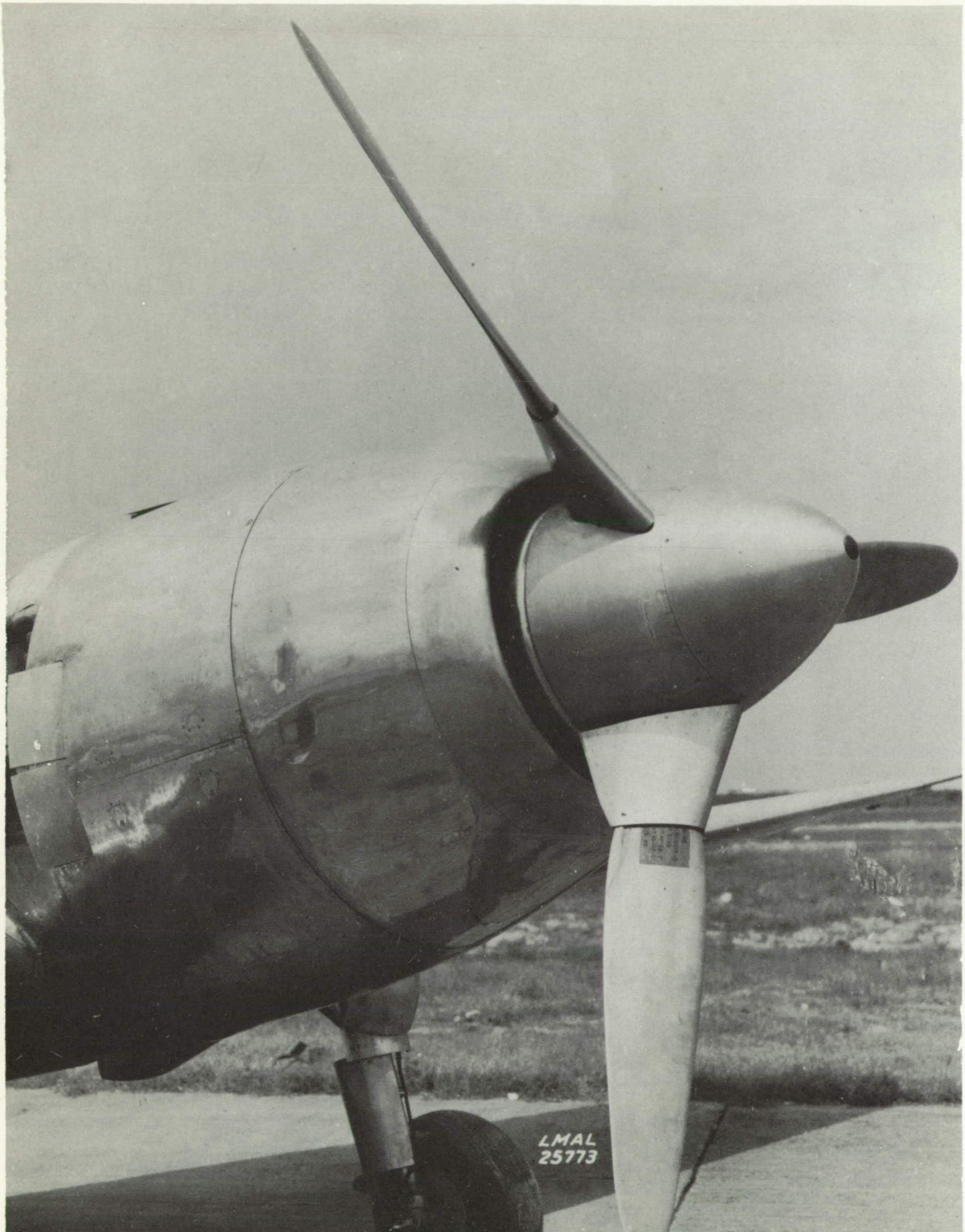
(a) Side view.

Figure 5.- NACA D_l cowling on XP-42 airplane.



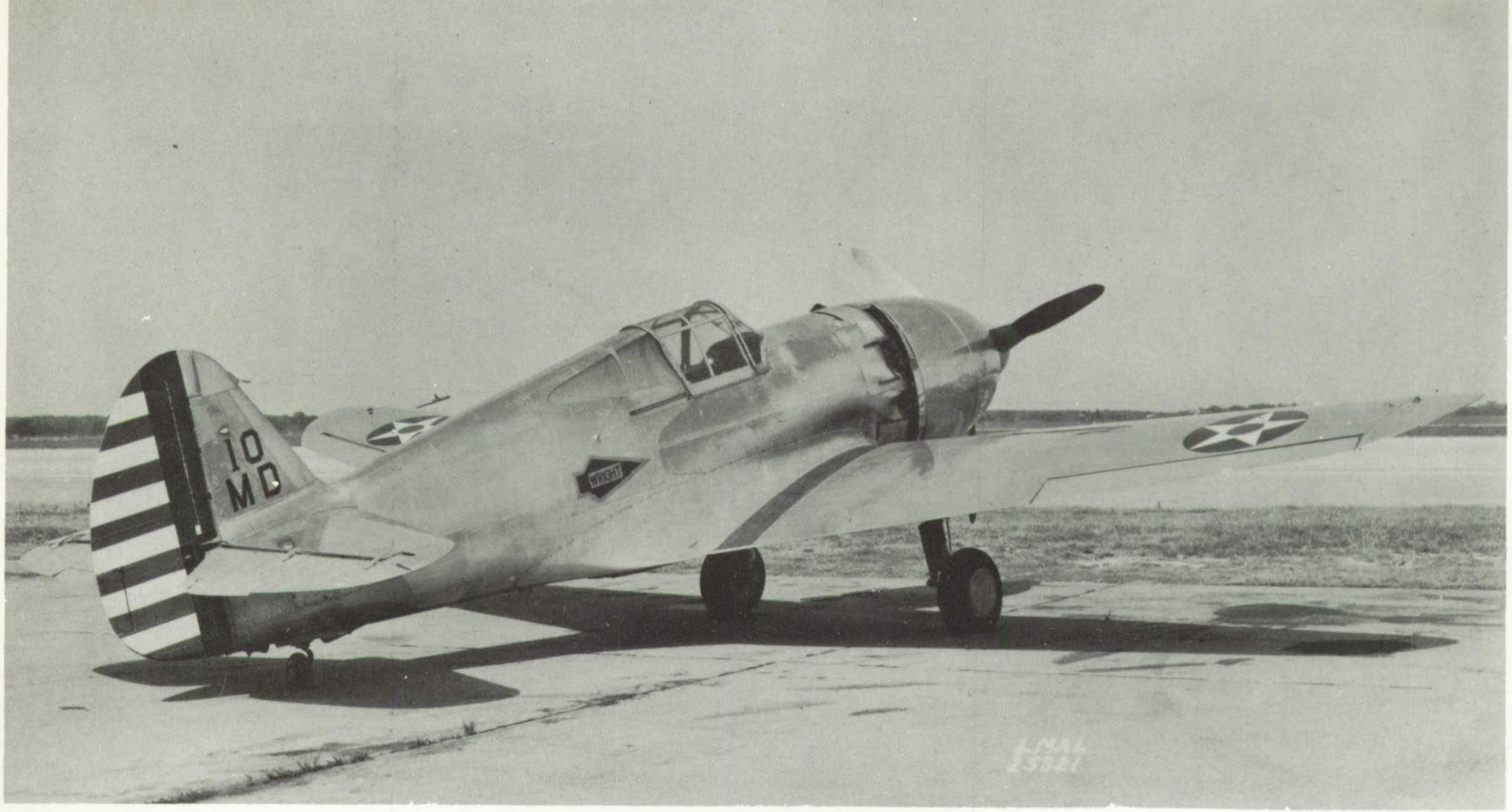
(b) Three-quarter front view.

Figure 5.- Continued.



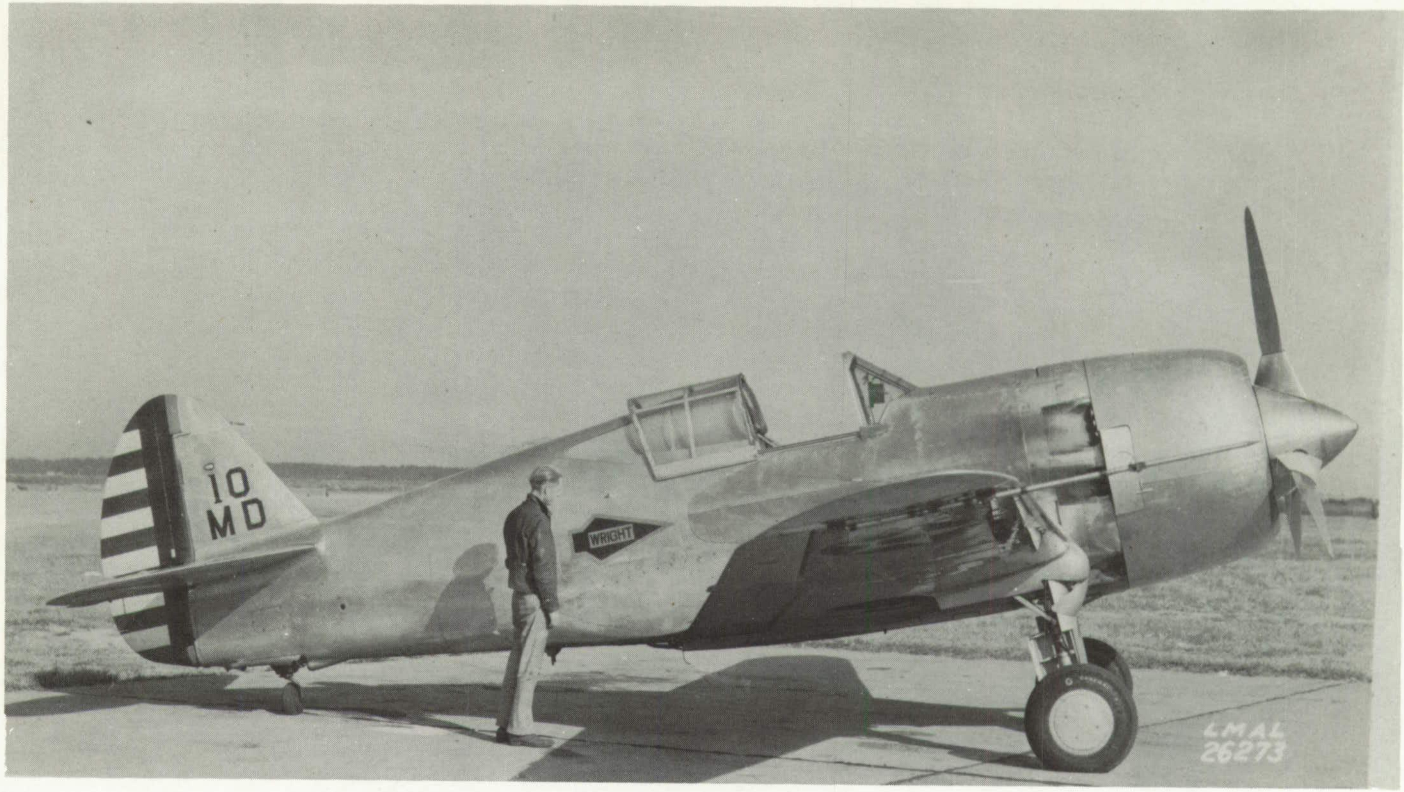
(c) Close-up.

Figure 5.- Continued.



(d) Three-quarter rear view showing modified cowl flaps.

Figure 5.- Concluded.

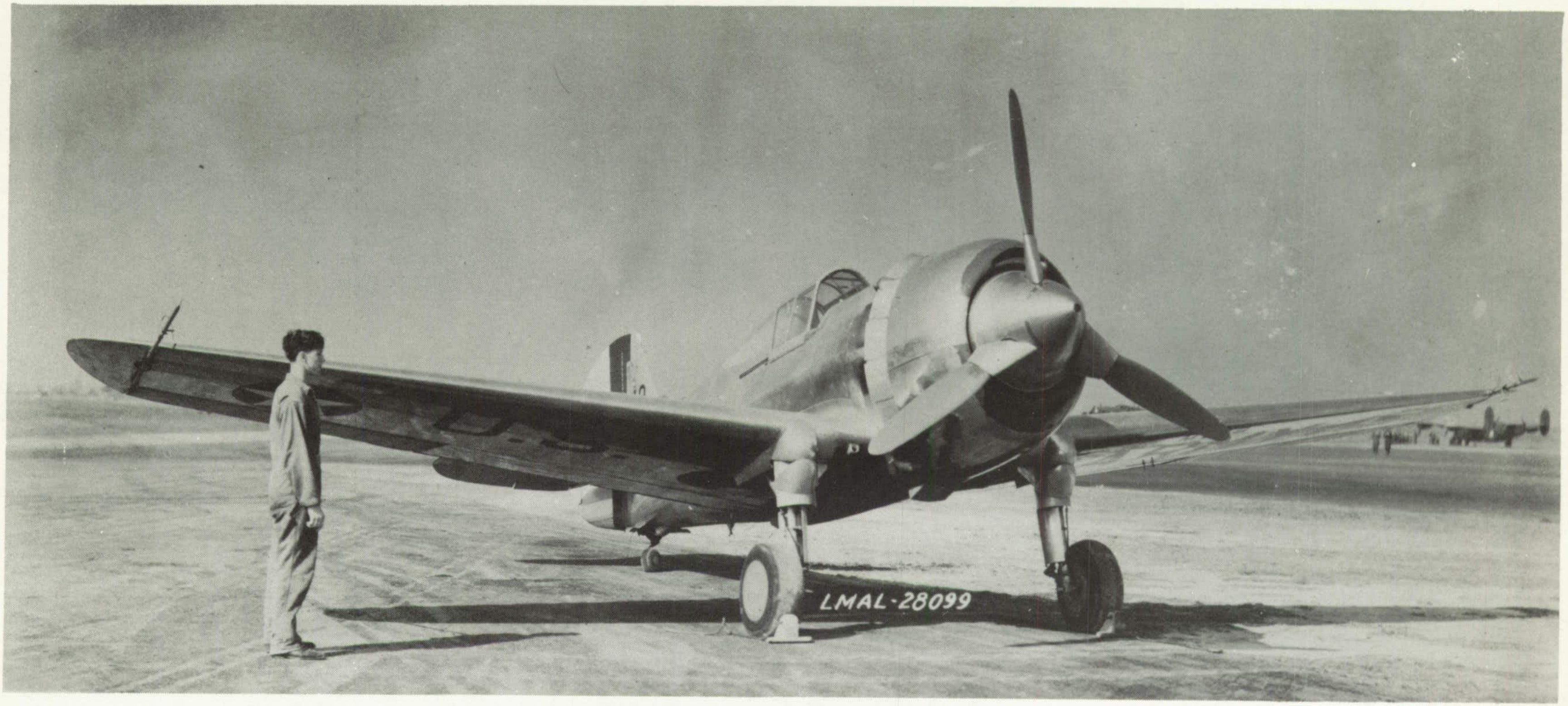


(a) Side view.

Figure 6.- NACA $D_{s.5}$ cowling on XP-42 airplane.

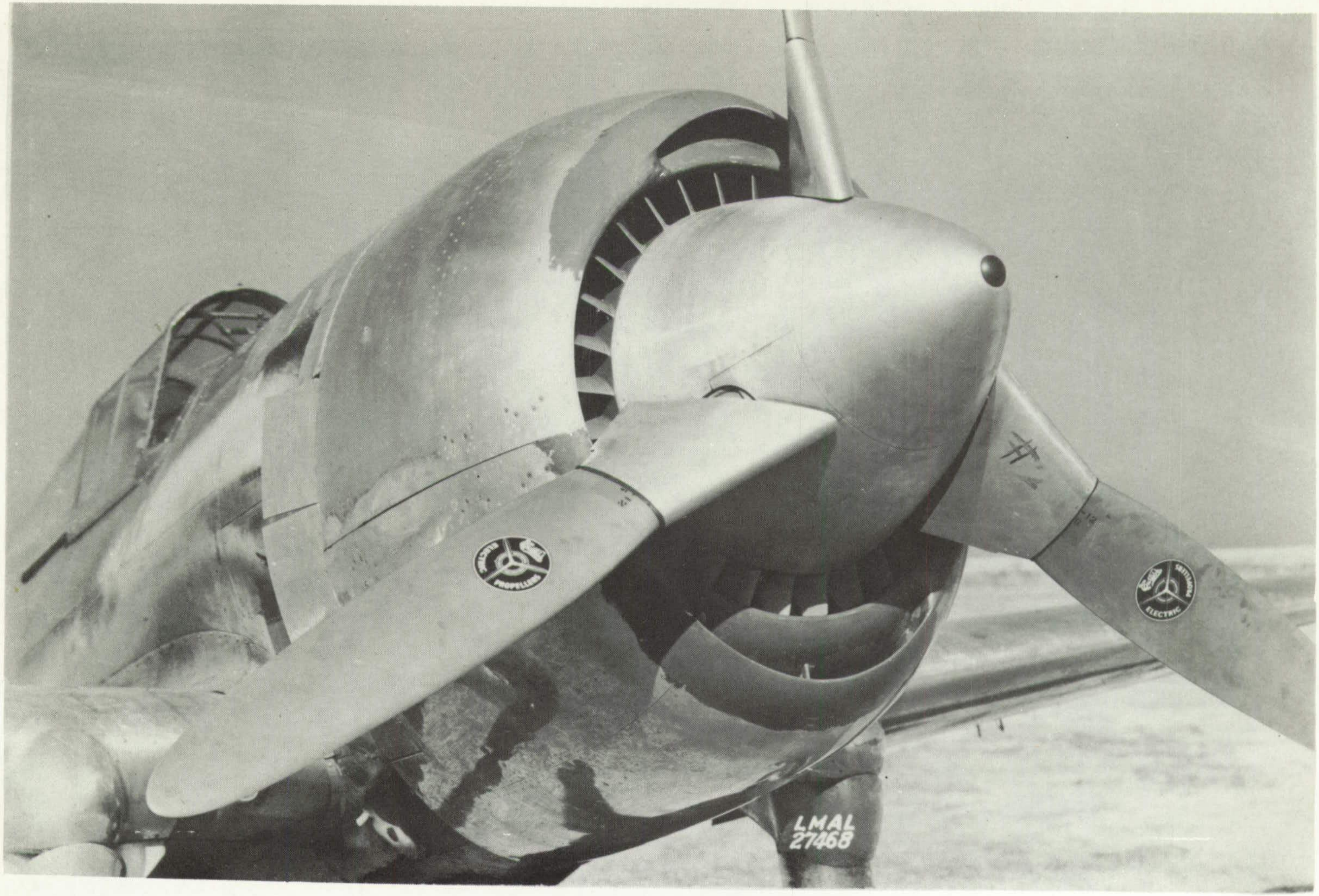
(b) Three-quarter front view.

Figure 6.- Continued.



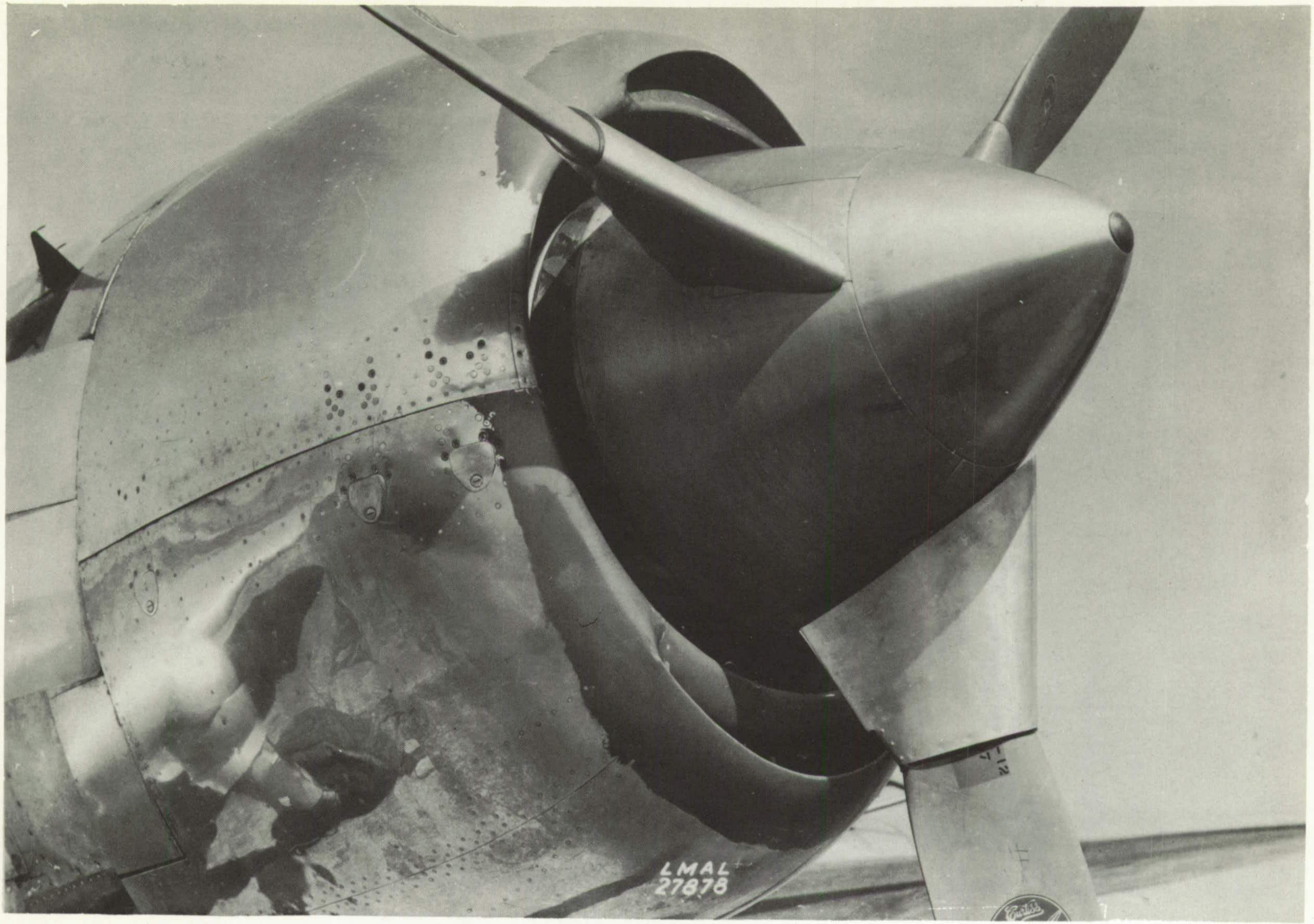
(c) Three-quarter front view showing modified cowl flaps.

Figure 6.- Concluded.



(a) With fan and cuffs 1.

Figure 7.- NACA $D_{s.3}$ cowling on XP-42 airplane.

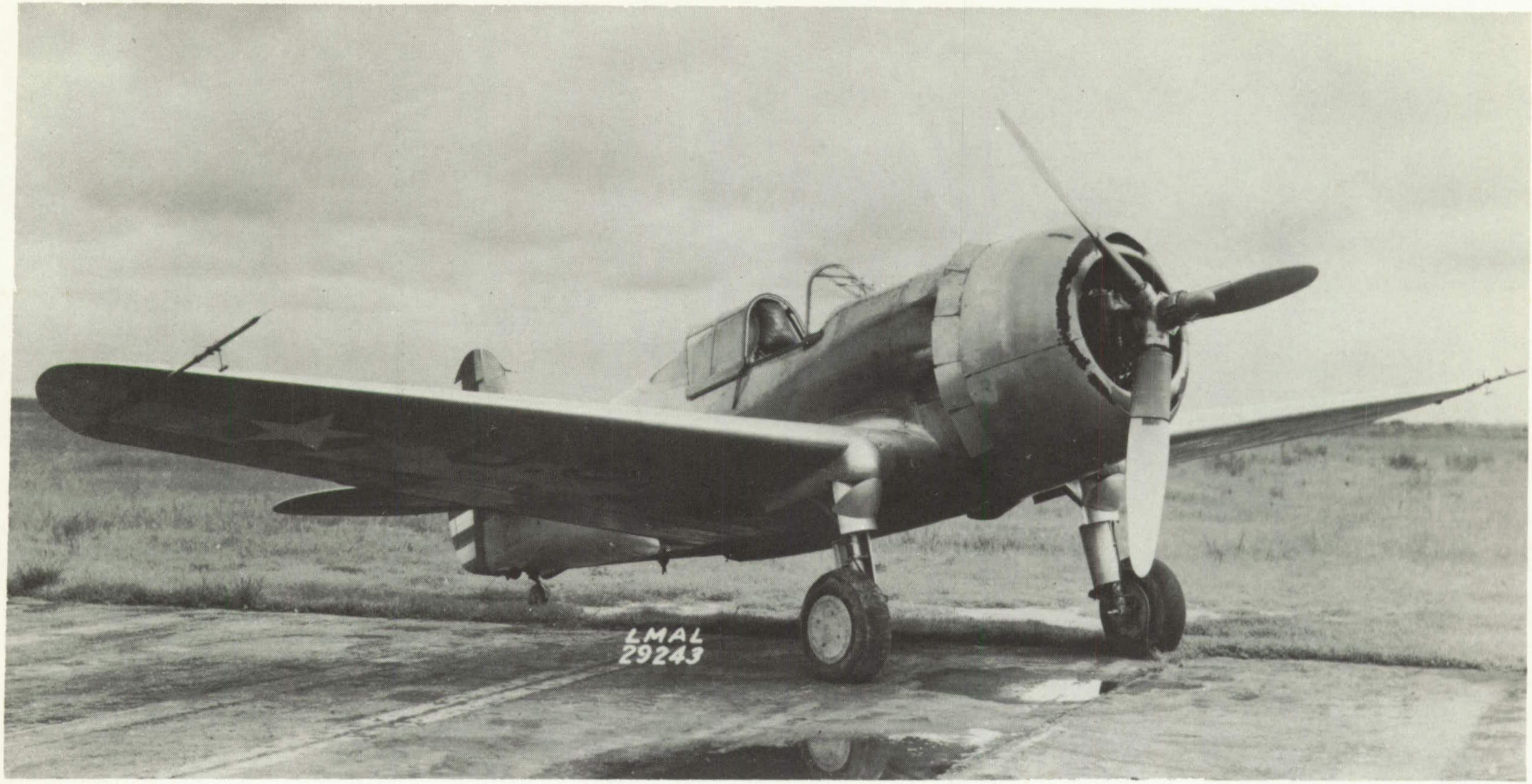


(b) With cuffs 2, without fan.

Figure 7.- Concluded.

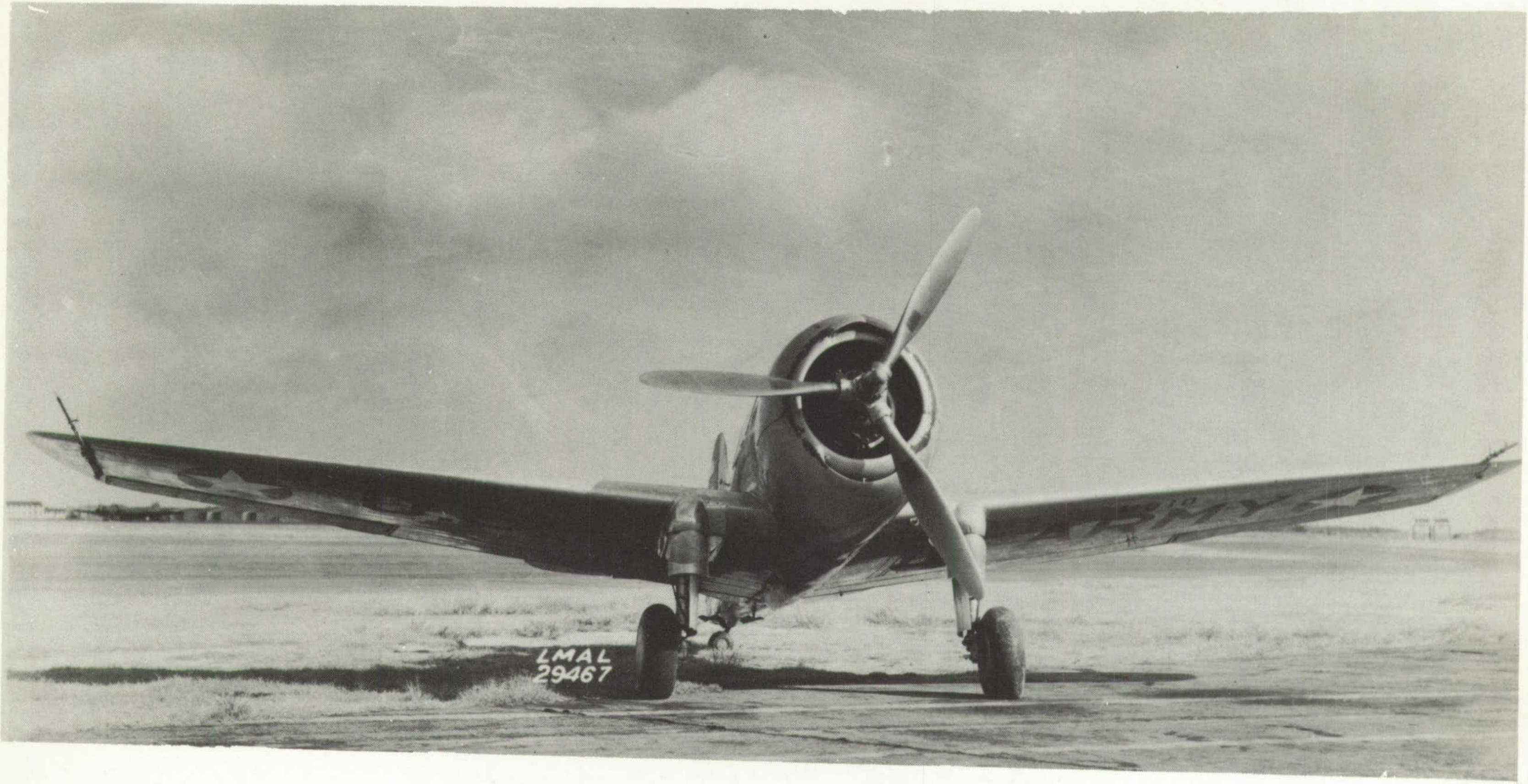
(a) With spinner and cuffs.

Figure 8.- NACA C cowling on XP-42 airplane.



(b) With cuffs, without spinner.

Figure 8.- Continued.



(c) Without cuffs or spinner.

Figure 8.- Concluded.

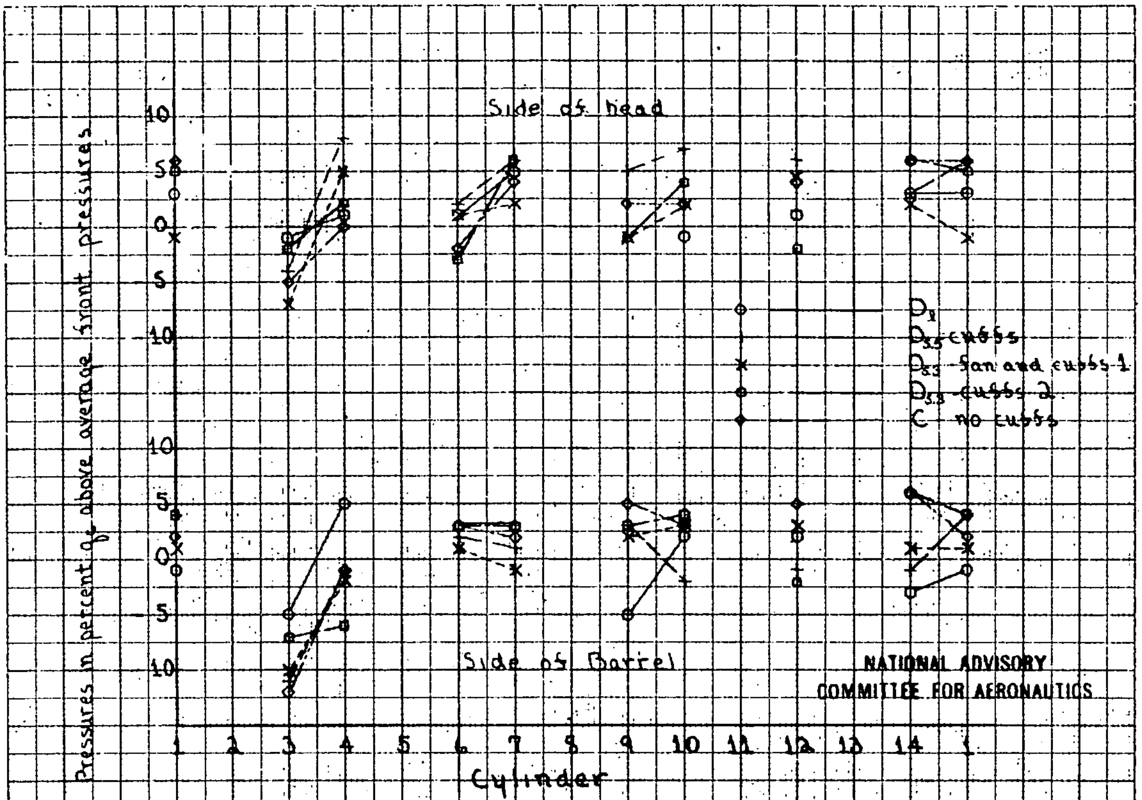


Figure 9. - Pressure distributions around engine in high-speed condition.

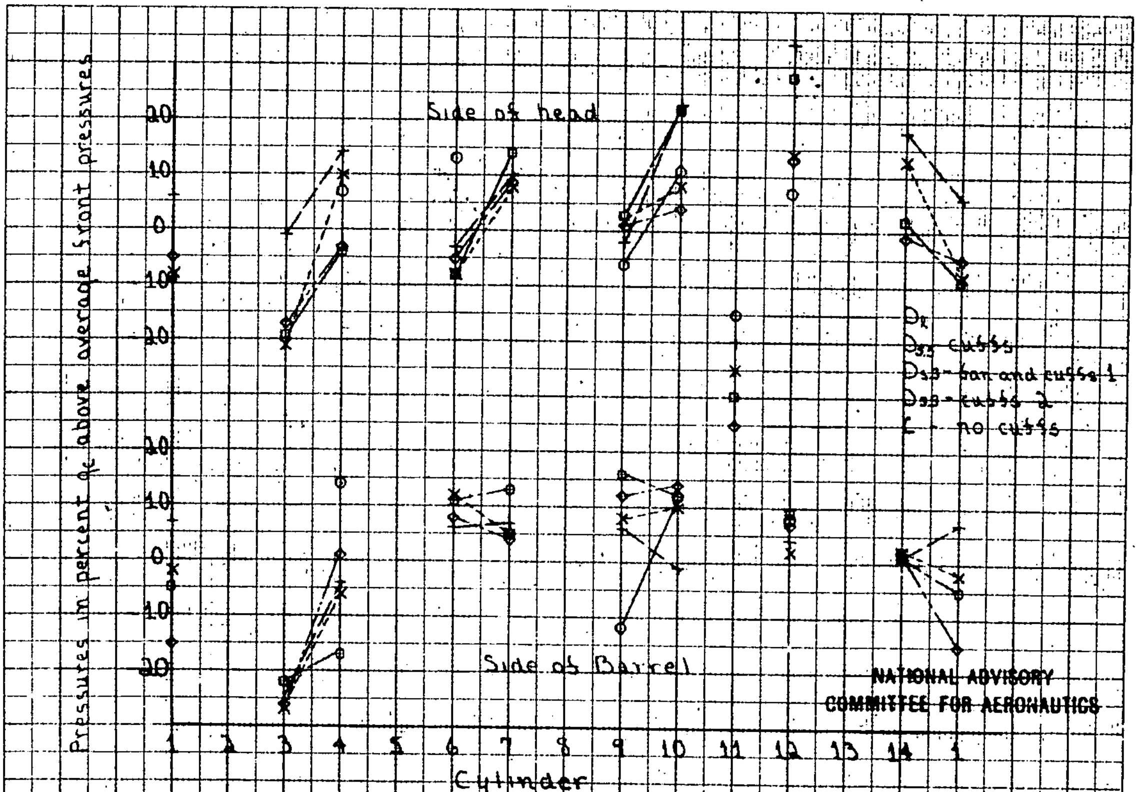


Figure 10. - Pressure distributions around engine in climb condition.

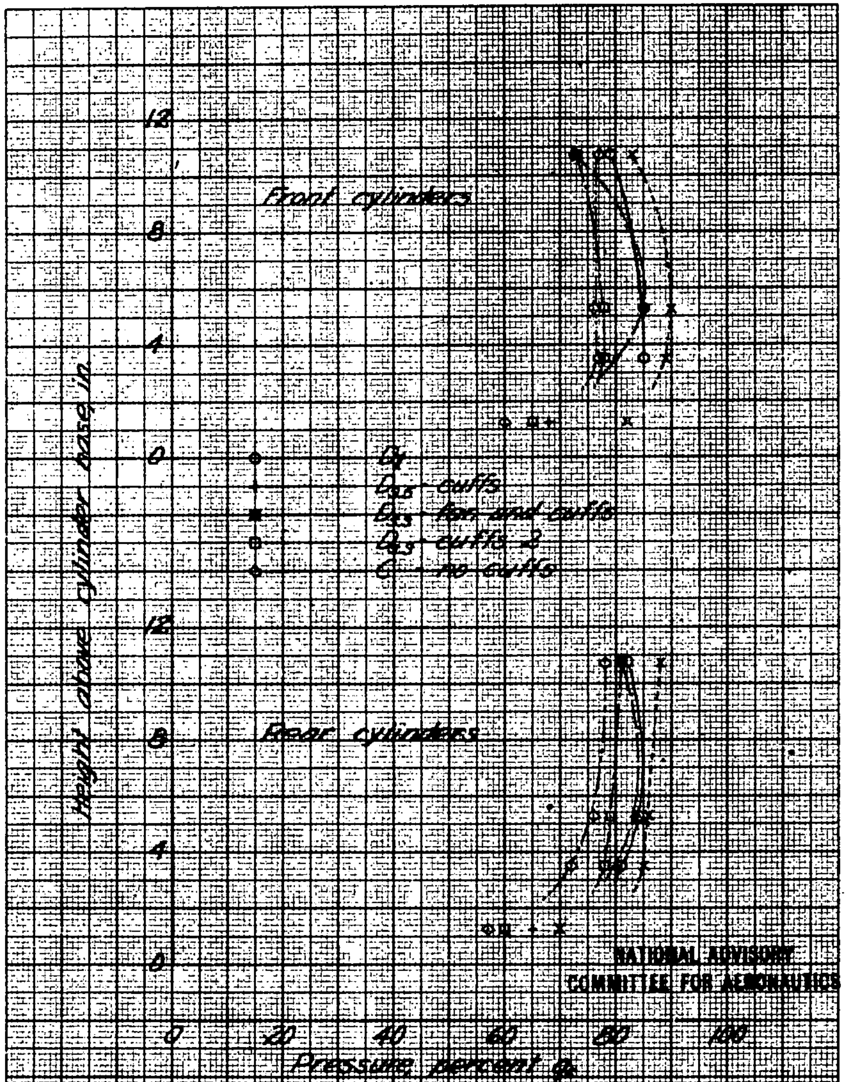


Figure 11. - Average radial pressure distributions in high-speed condition.

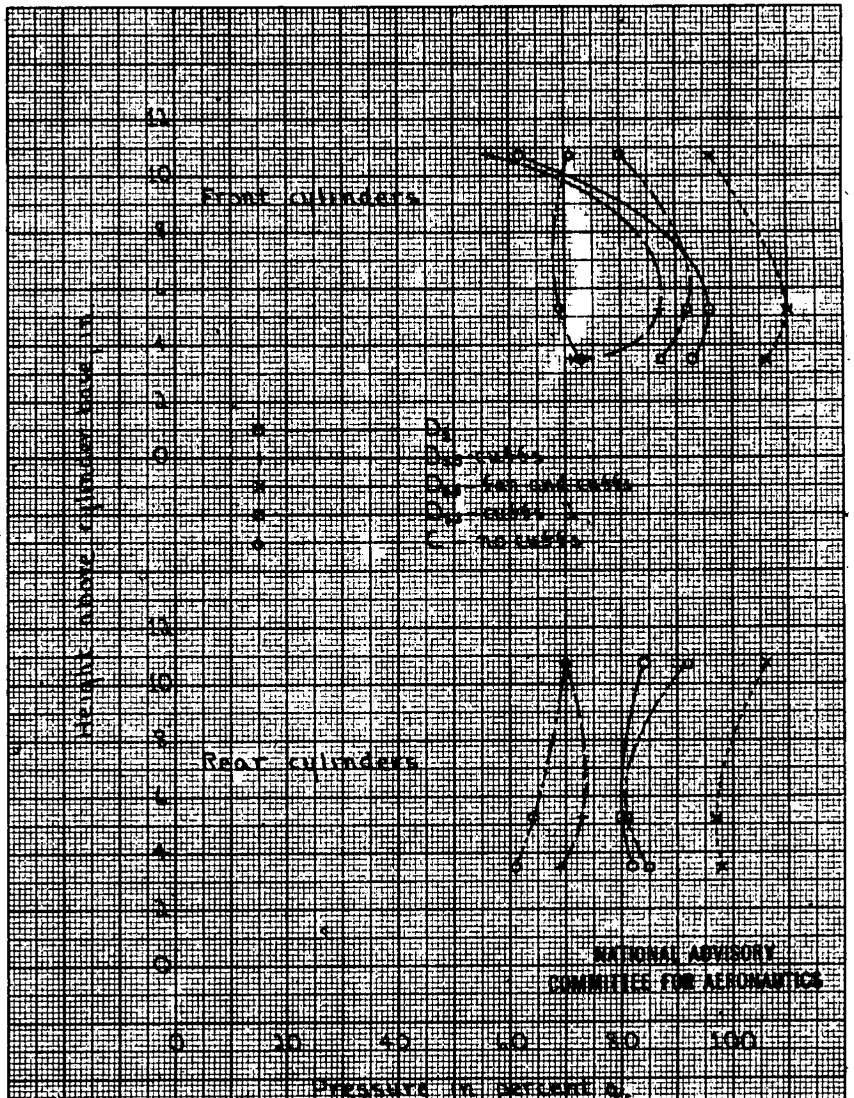


Figure 12. - Average radial pressure distributions in climb condition.

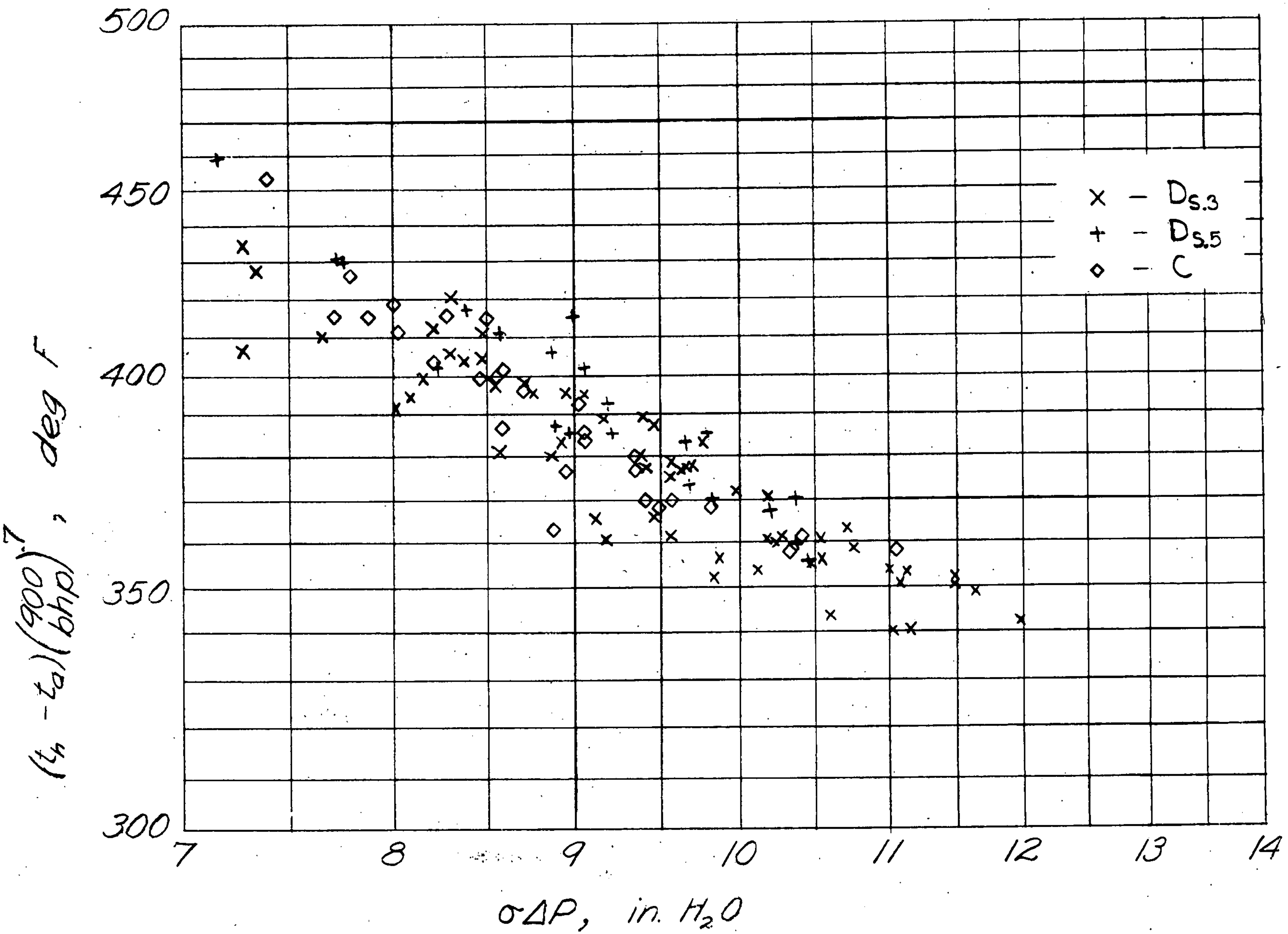


Figure 13. - Average cylinder-head temperatures, corrected to 900 bhp, from full-throttle level flight observations for three cowlings.

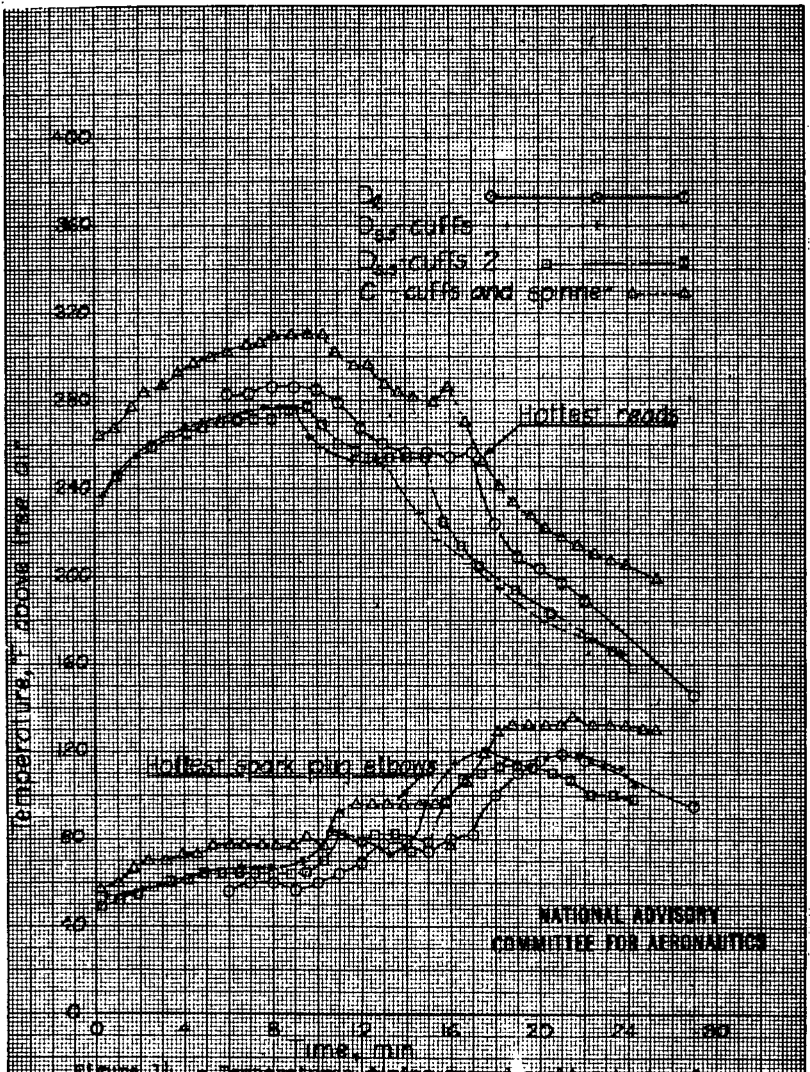


Figure 14. - Temperatures during ground-cooling tests of cowlings with cuffs.

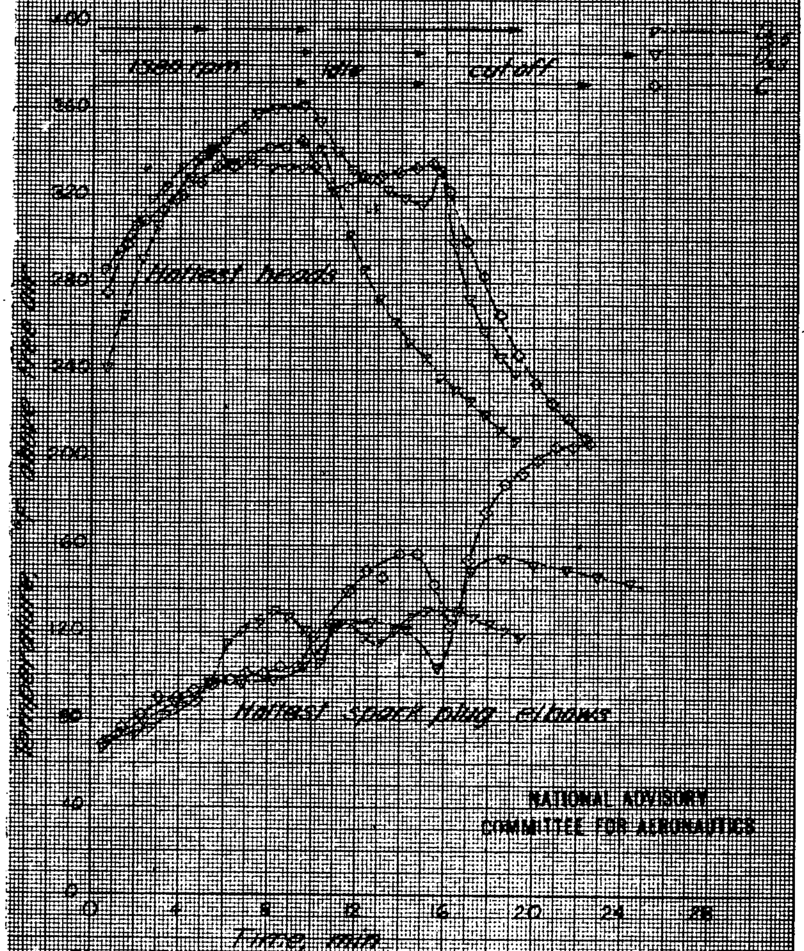


Figure 15. - Temperatures during ground cooling tests of cowlings without cuffs.